

Worlds of Flight

FLIGHT MANUAL

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TOM MIX SOFTWARE

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1.0 INTRODUCTION

WORLDS OF FLIGHT (WOF) is a "view" oriented flight simulation for the TRS-80 Color Computer. "View" oriented means that the user (or pilot) may determine his or her position by actually viewing the surrounding landmarks as opposed to using instruments which sense navigational references. This is a major departure from "instrument only" simulations which can be achieved through BASIC programs.

The aircraft modeled is an experimental, sport-trainer type and thereby lacks most of the instruments necessary for a purely instrument capability. However, most instrument maneuvers and procedures may be practiced. The craft is a light-weight, single place airplane with low wings, a "T" tail and a "pusher" prop mounted in the rear. A nose wheel which is both steerable and retractable is also modeled. The pilot is seated in the nose section and is surrounded by a high-visibility ("bubble") wind shield. Some aerobatics are possible including sustained inverted flight, aileron rolls, spins and stalls.

Instruments indicate: wheel brakes, gear position, flap position, fuel, elevator trim, stall, altitude, heading, indicated velocity, ground speed, rate of climb, engine speed, 2 min. turn, sideslip and pitch and roll attitudes. The engine may be started and shutdown and there are re-fueling stations at each airport which must be maneuvered to by taxiing if re-fueling is desired.

In terms of visual effects, WOF utilizes Hi-Res "wire" (or line) graphics to define landscape features. The pilot usually looks straight ahead; however, his or her viewing angle may be incremented in 90 degree intervals in the horizontal plane and in 8 degree increments in the vertical plane. A unique "RADAR" or overhead view visually pinpoints your craft's exact position and direction of travel. This is essential to instrument maneuvers or when flying above the cloud ceiling.

The program code itself was designed to be compatible with 32K CASSETTE systems as well as disk. TWO JOYSTICKS are required, however, Extended Basic is NOT NECESSARY. WOF features Hi-Res graphics, joystick control, realistic aircraft response and exceptional sound. The pilot may fly into and out of nine different "worlds" and control the weather conditions in each of these worlds. All worlds are fully 3-D in nature and contain objects or scenery which must be avoided (ex: towers, mountains, etc.). Every effort was made to maintain the technical "correctness" of the flight dynamics as well as the visual display out the window. The result is a machine language program written close to "the limits" of the 32K Color Computer, and a serious and challenging simulation of one of the most fascinating experiences of modern man... The Experience of Flight!

2.0 LOADING INSTRUCTIONS

2.1 CASSETTE — CLOADM ENTER . Program will Auto-Execute.

2.2 DISK — LOADM'FLIGHT' ENTER . Program will Auto-Execute.

2.3 LOADING NEW WORLDS

3.0 GENERAL PROGRAM OPERATION

This section describes the operational "flow" of WOF in general. It details how the simulation sequences through its various phases and how it is initialized (setup) and reset.

3.1 INITIAL DISPLAY

Initially the program goes through an opening display featuring an aircraft aileron roll. After the engine sound stops, the display may be exited by pressing the <ENTER> key. This sequence is never repeated and is followed by the DEFINE WORLDS phase.

3.2 DEFINE WORLDS

This portion of the program is entered after the initial display and after a CRASH or RESET of the simulation. This is the part of the program which allows the user to change or control the weather conditions in each of the nine worlds. Control is initiated by pressing the first letter of the first word in each of the controllable parameters. An example would be "W" for World select. After pressing the "W" a white square will appear over the position of the previous world number. This is your prompt to enter your selection which should be a number between "1" and "9", all others are ignored. Pressing a "3" will draw World #3, and allow the weather conditions to be changed in that world. The world displayed is the world in which changes may be made. It is also the world in which the simulation will begin unless the "B" key (BEGIN in world) has been pressed and a new world number specified.

Initially the DEFINE WORLD sequence starts in the middle world (#5 — the practice field). After a CRASH or a RESET the world displayed is the one in which the CRASH or RESET occurred. The following is a description of the control keys in DEFINE WORLDS and the limits of their inputs.

KEY	DEFINE WORLDS CONTROL DESCRIPTION
S —	Allows user to set the SPEED of the wind in knots. Two digits must be entered from 00 to 29 knots. All other keys or numerical values are ignored.

- F -- Allows user to set the direction in degrees FROM which the wind is blowing. Three digits must be entered from 000 to 359. All other keys or numerical values are ignored.
- C -- Allows the user to set the CEILING in feet below which the ground and other landmarks are visible through the aircraft windows. This parameter does not affect the RADAR view. Four digits must be entered from 0000 to 9999. All other keys or numerical values are ignored.
- B -- Allows the user to set the world in which the simulation will BEGIN. A single digit must be entered from 1 to 9. All other keys or numerical values are ignored. If unspecified, the simulation begins in the last displayed world before <ENTER> was pressed.
- X -- Allows the user to X-OUT or clear the weather conditions in all the worlds at once. A clear is defined as: SPEED 00; FROM 000; CEILING 9999. These are also the default values if the weather in a particular world is never specified.
- W -- Allows the user to select any of the nine WORLDS for the purposes of review or specification of weather conditions. Value is initially "5" and thereafter takes on the value of the world in which a CRASH or RESET has just occurred.
- ENTER -- Pressing this key exits the DEFINE WORLDS phase and transfers control to the flight simulation with the parameters specified during the DEFINE WORLDS sequence. The <ENTER> key is the only exit.

3.3 FLIGHT SIMULATION

This is the heart of WORLDS OF FLIGHT and can only be entered from the DEFINE WORLDS phase. The initial starting position is always at the south end of the runway within the runway scene.

In order to provide a much more realistic and detailed takeoff and landing simulation, a separate runway scene has been provided. Although the locations of the runways are different in each world, the runway scenes are the same and oriented on a north south heading. Shortly after takeoff the scene transitions from the runway graphics to the appropriate world scene. As your flight path crosses the boundaries of your current world, a transition takes place into an adjacent world. The layout of the nine worlds and the manner in which they are entered is given by the following diagram and table:

WORLD LAYOUT

#1 MOUNTAIN WORLD #1	#2 ARABIAN GULF	#3 PANAMA CITY
#4 DAHLGREN VA.	#5 PRACTICE FIELD	#6 MOUNTAIN WORLD #2
#7 ISLAND BAY	#8 MOUNTAIN WORLD #3	#9 POWER LINE RIVER

EXIT WORLD

EXIT BOUNDARY

NO.	NORTH	SOUTH	EAST	WEST	ENTRY WORLD NUMBER AND BOUNDARY
1	SOUTH #7	NORTH #4	WEST #2	EAST #3	
2	SOUTH #8	NORTH #5	WEST #3	EAST #1	
3	SOUTH #9	NORTH #6	WEST #1	EAST #2	
4	SOUTH #1	NORTH #7	WEST #5	EAST #6	
5	SOUTH #2	NORTH #8	WEST #6	EAST #4	
6	SOUTH #3	NORTH #9	WEST #4	EAST #5	
7	SOUTH #4	NORTH #1	WEST #8	EAST #9	
8	SOUTH #5	NORTH #2	WEST #9	EAST #7	
9	SOUTH #6	NORTH #3	WEST #7	EAST #8	

As the aircraft approaches the runway, the graphics will once again transition to the runway scene. The requirements for a transition to the runway scene are as follows:

*Altitude: Below the CEILING or 400 feet whichever is less.

*Range-to-Runway Threshold: 3888-4401 feet (9 pixels)

*East West Drift: \pm 864-978 feet off runway centerline (\pm 2 pixels; can be determined from the "IX"

RADAR view -- Section 4.4).

It should be noted that the representation of the runway or airport before the transition to the runway scene is very simple, (two reference marks to aid the final approach and an elongated rectangle as the runway itself). Its sole purpose is to provide a "target" to the pilot relative to which he or she may make maneuvers leading to a final approach.

As with real aircraft, control inputs have been simulated not to cause instantaneous responses. Characteristic of all aircraft is a slowly oscillating but damped pitching motion called PHUGOID which occurs in response to an elevator or throttle control command. For instance, suppose you are flying along straight and level, then pull the elevator stick back. Assuming that you don't stall, the airplane will first overshoot your new pitch attitude then undershoot it. This may continue for another cycle or so but, it will eventually stop or "damp". You will see this happen in 1 second intervals, which is the update rate of the simulation.

3.4 FLIGHT TERMINATION

The simulation is running continuously unless the < ENTER > or < R > keys are pressed. The < ENTER > key completely "freezes" the entire simulation including the engine sound. Pressing the < ENTER > key again, immediately causes resumption of the simulation. This feature may be used as many times as necessary.

The < R > key totally RESETS the simulation and goes back to the DEFINE WORLDS sequence.

A CRASH also causes a termination of the simulation preceded by a violent explosion, a color-filled screen and a data block in the upper left hand corner indicating your impact coordinates, and the world in which you CRASHED. If you CRASHED in the runway scene, your coordinates may have negative values, (see 8.0 MAPS). A CRASH is caused by:

- *an OUT-OF-TOLERANCE Landing
- *a landing or takeoff OFF THE RUNWAY
- *IMPACT WITH THE SCENERY (mountains, towers, etc.)

As before, pressing the < R > key causes a RESET from the CRASHED condition to the DEFINE WORLDS sequence where the worlds may be re-specified and the FLIGHT SIMULATION re-entered.

4.0 UNDERSTANDING AND CONTROLLING THE GRAPHIC VIEWS

WOF uses "wire" (or line) graphics to represent the various worlds. This method minimizes the memory required for each world and maximizes the speed at which the 3 D scenes can be drawn. As a result of some of the techniques used, WOF also provides "flicker-free" animation of the graphic scenes. For a more detailed discussion of "wire graphics", the user is encouraged to refer to the Appendix under the title "Representation of Graphic Scenes".

4.1 Wire Graphics

Wire graphics define only the outlines or contours of the objects they portray. To some, the "phantom" appearance of objects represented in this fashion causes some visual difficulty in actually interpreting what they are supposed to be seeing. Yet to others, the objects are obvious. All this is to say, that it may take some "getting used to" before some users begin to visually interpret the significance of every detail "seen" out the windows. For these reasons, a significant help has been installed into the simulation which should substantially aid in determining one's position and understanding of his or her surroundings. This is the ability to change ones viewing angle relative to the aircraft's orientation, or a PANORAMIC VIEW capability.

4.2 Panoramic Views

The ability to "Pan-around" is the equivalent of rotating your head (your viewing angle) left to right and up and down. This feature is controlled by the arrow keys. The < CLEAR > key rotates your view to straight ahead again just in case you get disoriented. Your view is normally depressed (pitched down) 8 degrees relative to the aircraft's pitch attitude. This is the natural look-down of the pilot's line of sight over the instrument panel. After the aircraft attitude (climb angle + angle of attack) exceeds an 8 degree pitch up, the forward looking view becomes AUTO-LEVELING. This is the equivalent of pitching the pilot's head one degree downward for each degree the aircraft pitches upward past 8 degrees. Consequently the center of the elevation view is never above the horizon. While this may be somewhat unrealistic (although there is a natural tendency to do it), the feature allows the pilot to view at least some of the horizon even in a steep climb rather than just sky. Once the craft pitches below 8 degrees, the "pitching motion" of the scenery will return. Above 1500 feet at a maximum climb, even auto-leveling does not insure a horizon as you fly to the "edge" of a world; use the < DOWN ARROW > key to get it back.

The cross-hair in the center of the straight ahead view indicates where the aircraft is headed. The cross-hair can be used to determine if the aircraft is above or below an object by incrementing the view UPWARD < UP ARROW > until the view stops moving downward in response to the key. This is where the AUTO-LEVELING feature takes over and the resulting view represents a true elevation view relative to the scenery. Press the < CLEAR > key to re-establish the normal 8 degree depression.

4.3 RADAR Views

Another related feature is the "RADAR" view which can be thought of as an overhead or "bird's eye" view (downward looking) of your world with a cross hair at your exact position. In this view the top portion of the "+" is pointing in your direction of travel or heading. The RADAR view is toggled (both entered and exited) by < SHIFT > < CLEAR >. It also has a variable magnification (ZOOM) feature which is controlled by the < Z > and < X > keys. Both the PANORAMIC and RADAR views are available at any time during the simulation. Liberal use of these features is recommended, especially the RADAR feature. When flying instrument practice or above the cloud ceiling the RADAR view is the only precise check available on position (the

clouds obscure the ground features out the aircraft windows).

The following is a summary of the VIEW CONTROL functions:

- < UP ARROW > -Elevate the vertical viewing angle 8 degrees.
- < DOWN ARROW > -Depress the vertical viewing angle 8 degrees.
- < RIGHT ARROW > -Move the horizontal viewing angle 90 degrees to the right (CW).
- < LEFT ARROW > -Move the horizontal viewing angle 90 degrees to the left (CCW).
- < CLEAR > -Set the horizontal view straight ahead with an 8 degree depressed vertical viewing angle.
- < SHIFT > < CLEAR > -Toggles the RADAR or overhead view. To exit press < SHIFT > < CLEAR > again. Also clears the ZOOM factor to the standard value of 1.
- < Z > -Enlarges (ZOOMS) the HADAR view by a factor of 2.
- < X > -Reduces the RADAR view by a factor of 2.
- < * > -"Inverts" the video of all graphic views. Press < * > to return to the original format.

NOTE: PANORAMIC views are relative to aircraft attitude.

5.0 THE INSTRUMENT PANEL AND FLIGHT CONTROLS

5.1 INSTRUMENTS

In order to describe the instrument display it is best that the instrument panel be visible. If it is not at this time, go through the loading process and exit the initial display. When world #5 appears press the "S" key followed by a "05". Then press the "C" key and enter 5000. You have just set the wind speed at 5 knots and the ceiling to 5000 feet in world #5. Now press < ENTER >. The instrument panel should appear. The instrument displays will now be discussed starting from left to right.

5.1.1 Elevator Trim Indicator (Trim)

This display indicates the position of the elevator trim. Trim initially begins in the center (0) position. Trim position is controlled by the joystick buttons. RIGHT BUTTON — Trim UP. LEFT BUTTON — Trim DOWN.

5.1.2 Fuel Gauge (FUEL)

This bar gauge indicates how much fuel you have. The rate of fuel loss is proportional to throttle position. At open throttle you have approximately 43 minutes of fuel in a full tank. When you run out, your engine will shutdown. If on the ground you're stuck without the ability to move your airplane, so you will have to RESET the simulation unless you can coast to the refueling area. If you run out of fuel in the air you'll have to perform a power-off landing and then roll to the refuel area (a next to impossible task!!!).

5.1.3 Knots of Indicated Air Speed (KIAS)

This instrument measures the speed of the wind flowing over the aircraft. This is a RELATIVE or INDICATED wind velocity NOT GROUND SPEED. If you have followed the suggested setup, this display should read 0005 knots because of the 5 knot wind that was previously set in. Now press the "V" key until the digital display "inverts". This is your ground speed, 0000. All aerodynamic forces on the airplane depend on the INDICATED or RELATIVE velocity, NOT ground speed. This feature is purely a navigational aid. Don't ever fly by the white-on-black ("inverted") numbers! Press and hold the "V" key again until they return to their normal black-on-white format.

5.1.4 Engine Speed (TACH)

This is the engine tachometer. It measures engine speed in 80 rpm intervals. A different engine sound is heard every 320 rpm. Wide open throttle is 2560; idle is 640. The forward back motion of the left joystick controls the throttle. The engine is STARTED by simultaneously pressing BOTH JOYSTICK BUTTONS. The engine is SHUTDOWN when on the ground by pressing the < S > key. The engine can't be shutdown in flight (why would you want to?!). Try it now. Make sure the brake is set (black cross in small box below CLMB readout), set it by pressing the < BREAK > key until the cross appears. Then start and shutdown the engine a few times and play with the throttle.

5.1.5 Stall Indicator (STALL)

This little square indicates that a stall is occurring. A black cross appears along with a raspy, stall-warning tone. This tone occurs whenever the angle of attack builds to 16 degrees. (See section 7.2.1 Stalls)

5.1.6 Artificial Horizon (Center Instrument)

This is the instrument most familiar even to non pilots. It visually conveys aircraft pitch and roll attitude. Your aircraft is represented by a colored "W" which does not move. Your horizon is represented by a dark line. This line translates up and down indicating changes in pitch attitude and rotates about the horizontal centerline of the instrument to indicate roll attitude. Note that although the representation of the airplane does not move, the instrument nonetheless is attempting to portray your aircraft's attitude relative to the horizon as if you were actually inside the aircraft and looking out the window. The short tick marks on the horizontal center of the instrument but just below the horizon line are spaced every 10 degrees of pitch attitude and move with the horizon. They also indicate where the "ground" is relative to the horizon. When flying level but inverted for example, these marks appear in the upper portion of the instrument indicating that you are indeed upside down.

The small tick marks located along the circumference of the instrument are also placed every 10 degrees of pitch attitude, thus helping to determine a quantitative measure of your craft's pitch attitude.

5.1.7 Sideslip Indicator (Ball - Below Artificial Horizon)

This instrument indicates whether or not your aircraft's turns are coordinated. It has been added for the sake of functional "correctness", however in a banked turn it has little or no dynamic effect on the turn itself. Since the consequences of uncoordinated turns (side forces on the pilot) can not be simulated, you will probably find little need to coordinate your turns (center the ball). But if you would be perfect, apply rudder in the direction of the ball. In non-banking flight, the rudder may be used to skid-turn but this is not a standard procedure. For this very reason rudder "power" has been purposely made rather weak (can only produce 2 deg/sec).

5.1.8 Altimeter (ALT)

Just below the sideslip indicator is the ALTIMETER. It always reads altitude above the ground or above ZERO absolute altitude. The runway is always at "0" altitude and all the various world features are also referenced to a "0" altitude base.

5.1.9 Compass (HEAD)

This compass reads relative to true North. It has one special feature. When banking to turn the heading readout goes to an "inverse" video display whenever the aircraft is in a 2 MINUTE TURN (3 deg/sec turn rate).

5.1.10 Rate-of-Climb Indicator (CLMB)

This readout displays the aircraft's rate-of-climb or rate of descent in feet per minute. Descents are indicated by a minus sign. The readout has a dynamic range of -999 to 9999 feet per minute.

5.1.11 Brake Indicator (BRKE)

Just below the rate-of-climb indicator is a small square indicating whether the wheel brakes are set. If set, a black cross appears in the box. Brakes are toggled on and off by the <BREAK> key while on the ground but may not be set while flying. These brakes are strong enough to hold against a max. throttle "run-up" and are the only positive way of completely stopping the aircraft once it is rolling.

5.1.12 Flap Indicator (FLAP)

This bar gauge indicates the aircraft's flap position in a qualitative sense. The flaps may be lowered to 60 degrees in 10 degree increments. This is denoted by an incremental lengthening of the bar gauge. The <SPACEBAR> lowers the flaps; the <-> key raises them again.

5.1.13 Gear Indicator (GEAR)

This bar gauge is very similar to the flap gauge. It indicates the gear position. The minimum length indicates gear up; the maximum, gear down. The <SHIFT> <UP ARROW> starts the gear raising process. The <SHIFT> <DOWN ARROW> starts the gear-lowering process. Gear may not be raised while on the ground.

5.2 Flight Controls

Real aircraft are flown by stick or yoke back pressure. The motion of the aircraft and back pressures that the pilot feels on his controls (elevator, ailerons and rudders) communicate what additional control inputs, if any, are needed. Without some elaborate and expensive control simulator to hook up to your home computer, stick feedback pressure is impossible to simulate. And as for the motion of the aircraft... FORGET IT! (Now you're talking MILLIONS OF DOLLARS!!) However, model airplane enthusiasts fly without these feedbacks, although they can view the aircraft's attitude and usually have self-centering springs on their controls. So there is hope for joystick control even though some loss of realism is unavoidable. To date all programs similar to WOF have used keyboard controls for throttle, rudder, elevator and aileron. WOF was designed to have these four functions controlled by joysticks WITHOUT CENTERING-SPRINGS, however, the beginner may find the various deluxe sticks now available for the COCO more forgiving and easier to work with. If your joysticks have the spring option, it is suggested that at least the THROTTLE control remain "free-floating". Whether or not to spring-load the other controls is purely a matter of personal preference.

5.2.1 Joystick Control

The added realism of joystick control was worth the extra effort it took to make the system flyable. The user should be aware of how the controls are implemented so that adjustments (if necessary) may be made in the manner in which control is used. Here is a descriptive summary of the joystick controllers.

5.2.1.1 Throttle

The FORWARD/BACK motion of the LEFT STICK produces THROTTLE changes in very small increments. Forward stick opens the throttle; backward stick closes it. Control is divided into 32 parts; the backward 8 parts of which cause no additional reduction in engine speed. This was done to allow the pilot a good deal of latitude in maintaining the 840 rpm required for TAXIING while moving the same stick left and right for the purposes of steering the nose wheel. It is easy to input throttle while attempting rudder control and since the TAXI condition is defined for a 640 idle, a large tolerance to throttle position was provided between the 640 requirement and the "all-the-way-back" mechanical limits of the stick.

The throttle is the most detailed or refined of the stick controls. Every nudge of the throttle (above 640) is likely to cause a change in the TACH. Engine speed may be adjusted in 80 rpm intervals from 640 to 2560. Since this control provides well defined thrust characteristics, THROTTLE can and should be used to make SMALL ADJUSTMENTS in the RATE OF CLIMB of the aircraft. For example, suppose you are flying at 70 knots and climbing at 120 fpm and you want to level your flight at 70. You could a) push the elevator stick forward but you may speed up since this is a coarse attitude control; b) trim down. This may work since the trim control is much finer elevator control but you may still speed up; c) REDUCE THROTTLE (probably 160 rpm) and presto! — straight and level at 70 knots without ever touching the trim or the elevator. Want to climb at 70 knots? . . . throttle up. Want to dive at 70 knots . . . throttle back.

5.2.1.2 Elevator

The FORWARD/BACK motion of the RIGHT STICK controls the elevator position and is the most coarse pitch attitude control. The stick is divided into 19 control zones, 9 forward of center and 9 back with a no-control or dead band in the center. Each control zone represents 2 degrees of elevator deflection, (+/- 18 degree limit). The EXTREME positions of the stick will almost always CAUSE A STALL. Stay away from these limits and be reminded of the fact that the limits that the computer "sees" are electrical and considerably BEFORE THE LIMITS OF MOTION OF THE STICK ITSELF. It is always best to operate in the first 3/4 th's of the stick range

As mentioned before, the throttle should be used to control the rate of descent or climb at a constant speed. However, the combination of ELEVATOR and ELEVATOR TRIM (the joystick buttons) controls the equilibrium VELOCITY of the aircraft at a constant throttle setting. For example, assuming a wide-open throttle, the elevator stick would need to be nearly centered (trim at 0) with the aircraft "clean" (gear up - flaps up) to cruise straight and level at 90 knots (104 mph). Pushing the stick slightly forward will cause a dive but no longer at 90 knots. As a result the engine may overspeed and the airspeed increase to over 100 knots. Pulling back on the stick will cause a climb but once again not at 90 knots; maybe 80, 70, 60, or even as slow as 50 knots. Since almost all maneuvers are specified at a particular indicated velocity (KIAS), the elevator/trim combination becomes the primary control of airspeed at a constant throttle setting. For instance, suppose you are level at a 60 knot cruise, but would like to be straight and level at 90 knots. You must do two things at once; open the throttle (causes a climb) and slowly push the stick forward (cancels the climb caused by throttle). Small adjustments can be made by the elevator trim to maintain level flight. When this is done, look at your airspeed. . . 88 to 92 knots in level flight.

5.2.1.3 Aileron

The LEFT/RIGHT motion of the RIGHT STICK causes a roll rate which is proportional to the stick's position off center. Once again, due to the lack of back pressure, some compromises have been made. There are only 3 rate proportional control zones on either side of center with a sizeable no-control zone in the center. This dead zone was made large enough so that control could be predictably stopped by placing the stick at it's approximate center. The first third of travel away from center gives a gentle 2 deg/sec roll rate (CW - to the right, CCW - to the left). The second third of travel gives 6 deg/sec and the FINAL THIRD is 20 deg/sec and should be used ONLY WHEN DOING AILERON ROLLS or when a large roll correction is necessary. For normal flight (especially landings) this control zone should be avoided! The large width of the control zones make it easier to find a predictable roll rate and somewhat make up for the lack of stick pressure.

5.2.1.4 Rudder

The LEFT/RIGHT motion of the LEFT STICK controls the aircraft's rudder and nose wheel. When on the ground this stick controls the nose wheel. In the air it controls the rudder. It has a large dead band center and 2 large control zones to either side. While on the ground the nose wheel gives a 4 deg/sec turning rate in zone 1 and 8 deg/sec in the extreme zone. In the air the turning rates due to rudder are 1 and 2 deg/sec, respectively. Note that the rudder is the only way to steer the aircraft on the ground.

5.2.1.5 Elevator Trim

The ELEVATOR TRIM is controlled by the JOYSTICK BUTTONS. The right button trims up 1 degree and the left button trims down 1 degree of elevator. An elevator trim range of +/- 4 degrees is available.

5.2.1.6 Engine Start

Simultaneously pressing BOTH JOYSTICK BUTTONS starts the aircraft's ENGINE while on the ground. (You are not allowed to shut down the engine in flight, so you won't need to restart it!)

5.2.2 Keyboard Flight Controls

5.2.2.1 Flaps

The <SPACEBAR> LOWERS the FLAPS in 10 degree increments. The <-> key RAISES the FLAPS 10 degrees. Flaps affect aircraft trim.

5.2.2.2 Gear

The <SHIFT> <UP ARROW> keys start the GEAR UP sequence. The <SHIFT> <DOWN ARROW> keys start the GEAR DOWN sequence. Gear position like the flaps affect the aircraft's trim.

5.3 Aircraft Performance

The following is a summary of the simulated aircraft's performance characteristics:

MAXIMUM GROSS WEIGHT	600 LBS.
ENGINE HORSEPOWER	40 HP
FUEL CAPACITY	15 GALLON
BEST RATE OF CLIMB	1020 FPM @ 60 KTS
BEST CLIMB ANGLE	900 FPM @ 50 KTS
MAXIMUM CRUISE SPEED (CLEAN)	90 KNOTS
MAXIMUM DIVE SPEED (CLEAN)	120 KNOTS
(SIMULATION LIMITS THE ALLOWABLE DIVE ANGLE SO THAT AIRCRAFT STRUCTURAL LIMITS ARE NEVER EXCEEDED)	
SERVICE CEILING	8960 FEET
STALL SPEED (CLEAN)	48 KNOTS
STALL SPEED (GEAR AND FLAPS)	42 KNOTS
MINIMUM TAKEOFF ROLL	864 FEET
MINIMUM LANDING GROUND ROLL	506 FEET
FUEL CONSUMPTION RATE	2.1 GAL/HR MAX THROTTLE
MAXIMUM RANGE & ENDURANCE	109 MI IN 1.9 HRS @ 50 KTS @ LESS THAN 1500 FEET @ 960 RPM
MAXIMUM ROLL RATE	20 DEG/SEC (AILERON POWER LIMITED BY SIMULATION FOR BETTER "FAST ROLL" CONTROL)
INVERTED FLIGHT TIME	SAME AS NORMAL FLIGHT (FUEL AND OIL SYSTEM IS PRESSURIZED)

5.4 Special Feature Controls

The following controls do not directly affect the flight of the aircraft. They are, however, special aids which are available to the pilot.

5.4.1 2 Minute Turn Indicator

Although a standard 2 min. turn indicator is not present on the instrument panel, an indication of this standard turn is available by way of the compass (HEAD) readout. Whenever the aircraft is in a 2 min. turn, the HEAD readout will go to an inverse video format (white numerals on a black background).

5.4.2 The V Key — Ground Speed Indicator

GROUND SPEED (previously mentioned in 5.1.3) is not usually available on demand to small airplane pilots, but since it is calculated by the simulation it has been made available. To obtain your ground speed in knots, press and hold the < V > key until the KIAS readout goes to an inverse video format. The inverse video indicates that the speed reading is GROUND speed. Press the < V > key to return to the normal display format and Knots of Indicated Air Speed (KIAS).

5.4.3 The W Key — Weather Information

Pressing the < W > key will cause a data block to appear in the upper left of the aircraft window. This data block identifies the current world and its WEATHER CONDITIONS. This display automatically disappears after 5 seconds. World identification and weather information will also appear during a transition to another world or any transition to the runway scene. The data block accompanying the runway scene will identify itself as "RUNWAY" WORLD #1 to 9. So if you are confused as to which world you are in, or you have forgotten the weather info, just press the < W > key.

5.4.4 The TAXI Feature

In order to provide for stable and controllable maneuvers off the runway, a taxi feature has been added. It provides a steady 10 knot GROUND speed TAXI, and allows the aircraft to move off the runway for the purposes of re-fueling or just taxiing around. This is how a TAXI is performed:

- *Set the brakes so that the GROUND SPEED is 0000
- *Throttle back and maintain an idle of 640 rpm
- *Release the brake

As soon as the throttle is moved above 640 (dead idle) the simulation will assume that you are throttling up for takeoff and your craft **MUST BE ON THE RUNWAY** to avoid a CRASH.

5.4.5 The < S > Key — Engine Shutdown

The S key shuts down your engine while on the ground. The key is ignored in flight.

5.4.6 The < F > Key — Refueling

Both ends of the runway have a refueling station. Each station consists of three refueling locator marks and an adjacent fuel storage pyramid. To refuel, establish a TAXI and switch to the overhead or RADAR view, (this is not required, it just makes it easier). Then maneuver with the rudder control (nose wheel) until your position cross-hair is heading inside of the three marks. Set the brakes so that your airplane stops inside of the three locator marks. Now shutdown your engine. When this is complete, press and hold the < F > key until the refueling sound is heard. If you are really low it will take a while, (since you have such a small tank, they use teaspoon!) Leave the other controls alone while refueling. Once you are full, restart your engine and be on your way.

6.0 NAVIGATION AND COLLISION AVOIDANCE

This section assumes that some pilots would like to know how the simulation handles navigation and that you would like to know what situations cause a CRASH.

6.1 Runway Scene

6.1.1 Landing Requirements

The following conditions must exist at touchdown (ALT = 000) in order to produce a successful landing which is accompanied by "WHEEL NOISE"; otherwise a CRASH will result.

POSITION: Completely ON THE RUNWAY at touchdown and DURING ROLL OUT. In other words, stay on the runway until you have stopped.

GEAR POSITION: Completely DOWN and locked.

DESCENT RATE: Less than or equal to 360 feet per minute. 360 fpm is a HARD landing but survivable. HARDER landings are assumed to cause aircraft damage or a CRASH.

ROLL ATTITUDE: Less than or equal to 16 degrees either way.

HEADING: NOT restricted but remember when your nose wheel touches — you begin to turn on the nose wheel if your heading is not 0 or 180. Generally a few degrees either way is NOT critical.

6.1.2 Taxiing Around the Airport

After establishing a TAXI you may use the rudder to steer about within the runway scene. You must avoid running into objects with height such as the fuel tanks or the tower. The runway layout is detailed by MAP # 10. The locator marks are labeled "No Crash" and will NOT cause a CRASH. This is a good time to practice using the various views so that you will become accustomed to how things appear as you pass them, (taking off while looking backwards is kind of fun!). For example, taxi straight up the runway and switch to the RADAR view. Note the cross hair, it helps you determine when objects are directly ahead, directly beside or directly behind you. As the tower approaches directly to your left, switch back to the window view and increment your view to the left once (90 degrees). The tower should be going by. As it passes, increment to the left one more time (180 degrees) to see it as it moves behind you.

A side note here. It is possible to taxi right out of the runway scene into the world scenes, although at 10 knots, it wouldn't be fast. You still must avoid obstacles but you'll never be able to takeoff because you are not on the runway. Turning around and heading back to the runway will eventually get you back.

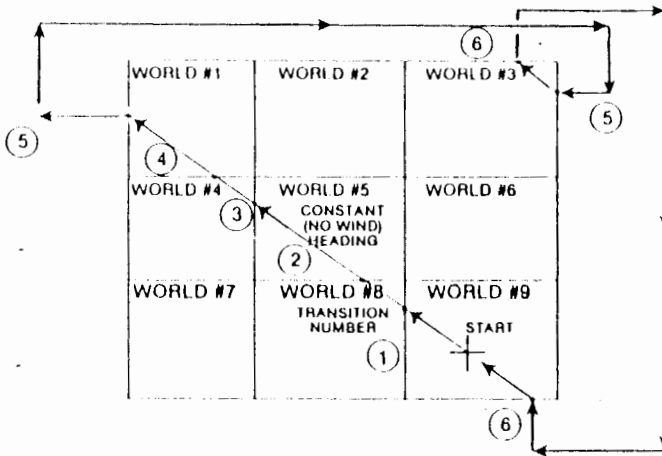
6.2 Within a World

Objects and scenery must always be avoided except in WORLD #5 (The Practice Field). The MAPS in Section 8.0 are accurate enough to navigate by with a high degree of precision. Remember to compensate for the wind if you are really serious about flying over a particular point at a particular time.

6.3 World to World

When a WORLD boundary is crossed, a transition to another WORLD occurs. The outside boundaries wrap around NORTH to SOUTH and EAST to WEST as described by Section 3.3. Navigation across multiple worlds is precise and repeatable since the worlds have truly common boundaries. So one may fly diagonally across WORLD #9, #5, and #1 (fuel permitting) and eventually end up on the same heading back at your initial starting position in WORLD #9. This assumes of course that you did NOT set the WINDS in these worlds, (see figure below).

EXAMPLE TRANSWORLD FLIGHT PATH



If the weather conditions are different in the world you are transitioning to, you will instantaneously (upon transition) be flying in the new set of weather. This could greatly upset the trim of your aircraft, so be forewarned. Also, when approaching "transition", check closely the "lay of the land" in the world you will be entering. There may be mountains of significant height on the borders. Without adequate altitude, you may transition SMACK INTO A MOUNTAIN. To be sure, once again, consult your MAPS (Section 8.0)

7.0 AIRCRAFT MANEUVERS

This section describes some suggested techniques for performing some rather basic aircraft maneuvers and a few aerobatics. These are by no means the only way to do things nor are they necessarily the accepted ways, but they do work.

7.1 A Suggested Procedure for Takeoffs and Landings

The following procedures assume NO WIND conditions. The AIRSPEED and TACH settings are APPROXIMATE. A variation of 2 knots and 160 rpm is NORMAL.

- * Taxi or move to the end of the runway which results in an UPWARD takeoff.
- * Steer to RUNWAY HEADING 0 or 180 degrees and stop (set brakes) in the center (approximately) of the runway.
- * Check TRIM position — It should be in the center.
- * Run the ENGINE up. Check TACH (should read 2560).
- * Center the RUDDER left to right. Center the ELEVATOR forward to back and the AILERON left to right.
- * Release the BRAKE.
- * Pull the Elevator stick back about half way at 60 knots.
- * At liftoff, retract the GEAR.
- * Climb at 60 knots. Adjust speed with gentle changes in the Elevator position.
- * At about 850 feet altitude, slowly reduce power to about 1440 rpm and adjust climb rate with gentle THROTTLE changes until straight and level at 950 to 1050 feet.
- * Begin 2 MIN. TURN at a constant altitude. Move the AILERON STICK about one third from center (gentle roll rate) until the HEAD readout goes to inverse video indicating a 2 min turn. CENTER THE STICK IMMEDIATELY. Add gentle power to maintain altitude if necessary.
- * When your heading is within about 10 degrees of the downwind leg heading, begin a gentle roll out (opposite one third AILERON STICK). When the wings are level CENTER THE STICK IMMEDIATELY. Reduce power to 1280 rpm for level cruise at 60 knots. Adjust power up or down to maintain altitude at 950-1050 feet.
- * You should be very close to your downwind heading (the lines on each side of the runway in WORLD #5). Small adjustments can be made by gentle banks or RUDDER control.

*When directly abreast of the downwind reference point (go to RADAR or increment your window view 90 degrees toward the runway to determine this), begin a 2 MIN TURN.

*After the turn is established, lower the gear and reduce power to 1120 rpm (never lower). Add FLAPS or trim down 1 degree to maintain a 480 fpm descent rate. At 10 degrees from the runway heading, begin a gentle (one-third stick) rollout to the runway heading. Add FLAPS to maintain 480 fpm descent.

*Make small adjustments in heading with RUDDER. Larger corrections with shallow banks. Be sure your view out the window is "< CLEAR > ed" ahead.

*RUNWAY SCENE should appear going through 400 feet altitude. Maintain descent.

*At 100 feet altitude, check the window cross-hair. If cross-hair is above or even with the threshold (beginning) of the runway, maintain descent. If it is BELOW the threshold, trim UP 1 degree (begin flare early). When the RUNWAY THRESHOLD DISAPPEARS from view, you are OVER THE RUNWAY.

*At 50 feet altitude, trim UP again whether you have already done so or not. At 20 feet trim UP ONLY IF YOU HAVE NOT ALREADY INCREMENTED TWICE. If you are really "slick" a third trim up at 6 to 8 feet with slight reduction in throttle should result in a borderline stalling touchdown.

*AFTER THE WHEEL NOISE IS HEARD, apply BRAKES IMMEDIATELY and push the ELEVATOR stick forward.

*Reduce throttle to 640 rpm. Stop. Release the Brake and TAXI to refuel or position the airplane for another takeoff.

NOTE: A "60 knot pattern" or race track around the runway is approximately 1.5 cross-hair widths off the runway centerline (9 pixels, when using the RADAR view with the standard magnification). Pattern altitude is 950 to 1050 feet and is normally entered at a 45 degree angle relative to the active (upwind) runway heading. Making 2 min. turns is not necessary but they do provide a very repeatable radius of turn (at a CONSTANT speed) and thereby aid in producing turns which roll out precisely on the runway centerline.

You also do not need to use ELEVATOR TRIM to control your flare at landing, however, its use is strongly recommended until you "get the feel" of "flying" the simulation. When using stick, the final flare can be delayed to about 25 feet altitude because the stick gives more control than the elevator trim, but be careful not to cause a stall (See Section 7.2.1). A final method of controlling your descent is of course throttle, so experiment a bit.

7.2 Aerobatics

All aerobatics should be performed with at least 1500 feet of altitude, 70 knots of airspeed and in a "cleared" portion of a world. The PRACTICE FIELD (WORLD #5) is a good place to try these because there is absolutely nothing to run into, save the ground itself.

7.2.1 Stalls

Stalls are caused by angles of attack at or above 18 degrees (plus or minus). Angle of attack is caused by ELEVATOR STICK and ELEVATOR TRIM controls. When these two control inputs combine to give a + / - 18 degree deflection or more a STALL will eventually develop. The reason a stall does not occur immediately, is because there is a RESPONSE LAG in both the control input and the aircraft's flight path turning rate, (the latter caused by inertia). A STALL will cause a counter-clockwise rolling motion of the aircraft (due to engine torque) along with a rapid drop of the nose. As with most light aircraft, stall recovery is almost automatic assuming that adequate altitude exists. However, the craft will stall again and again until the magnitude of the elevator deflection is decreased, so to insure complete recovery, move the elevator stick toward center and level your wings.

You may stall "proof" your aircraft by trimming down 2 degrees. In this way, extreme backward stick will not develop more than 18 degrees of elevator and thereby limit the angle of attack to less than its critical value. Take heed however; this condition could "bite" you if you fly inverted as forward stick will now stall EARLIER. A general rule in avoiding stall is to use the first 3/4 th's of the elevator stick travel away from center and to keep the trim within a couple degrees of center.

7.2.2 Aileron Rolls

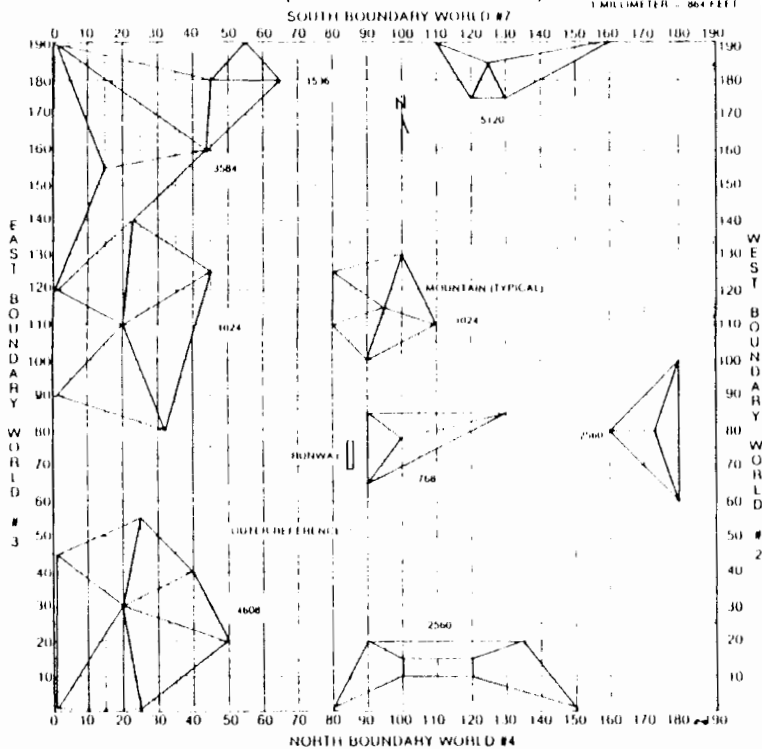
Aileron rolls make use of the extreme limits of the AILERON stick. Raise the nose a touch and then move the AILERON stick to one of its extreme limits. Try not to give elevator. When the altitude indicator is within 20 degrees of wings level, center the stick IMMEDIATELY. Now give gentle roll stick until the wings are level. Re-adjust your trim if necessary.

7.2.3 Inverted Flight

Raise the nose slightly, then give extreme, AILERON stick. When your altitude indicator is within 20 degrees of upside down, center the stick IMMEDIATELY and push the elevator stick forward slightly to maintain level flight. Now make gentle rolls until your wings are level. Re-adjust your trim if necessary. Remember that elevator and rudder respond in a "BACKWARDS" fashion now, and of course your window views will also be inverted.

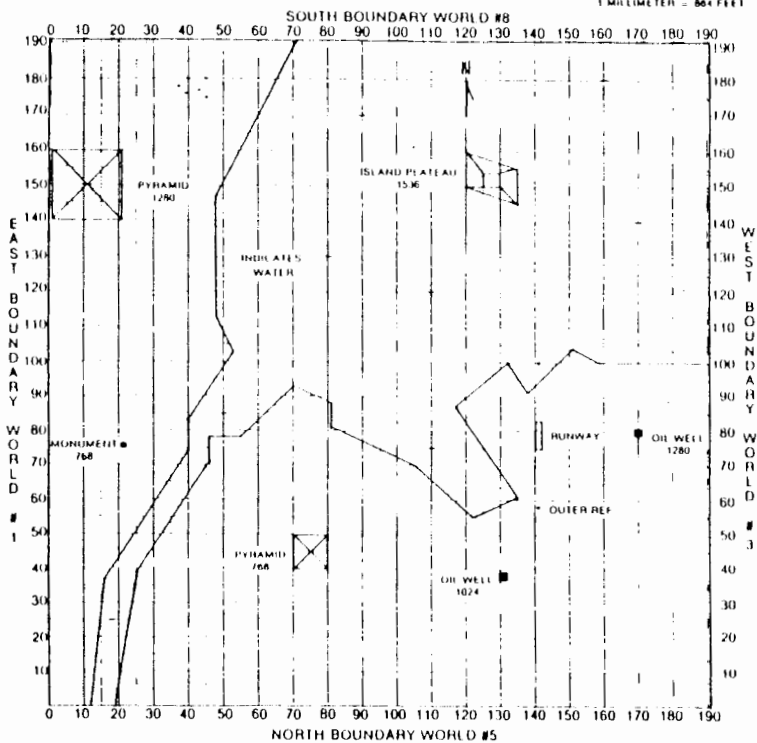
MAP 8.1 WORLD #1 (MOUNTAIN WORLD #1)

1 MILLIMETER = 864 FEET

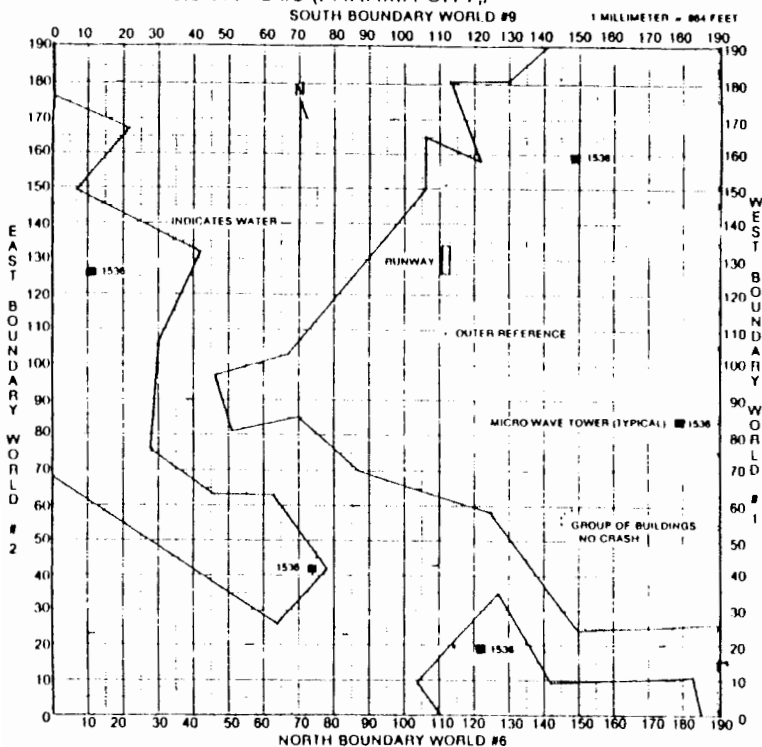


MAP B 2 WORLD #2 (ARABIAN GULF)

1 MILLIMETER = 864 FEET

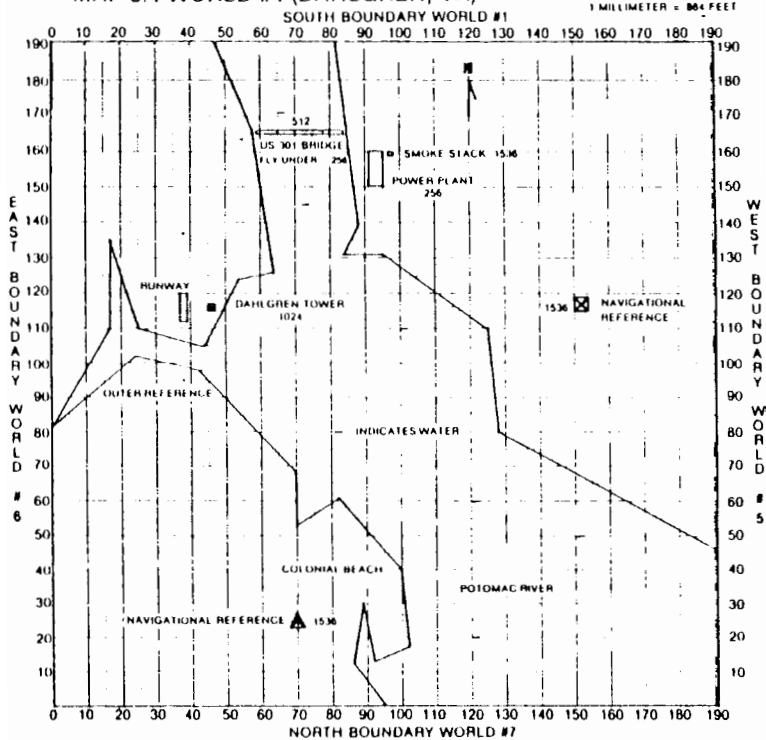


MAP 8.3 World #3 (PANAMA CITY)



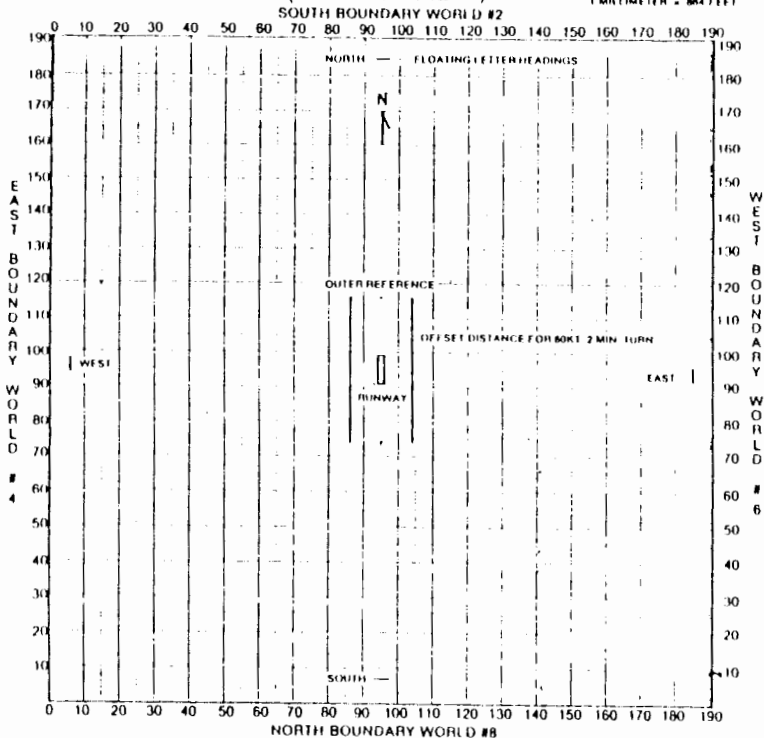
MAP 8.4 WORLD #4 (DAHLGREN, VA)

1 MILLIMETER = 80 FEET

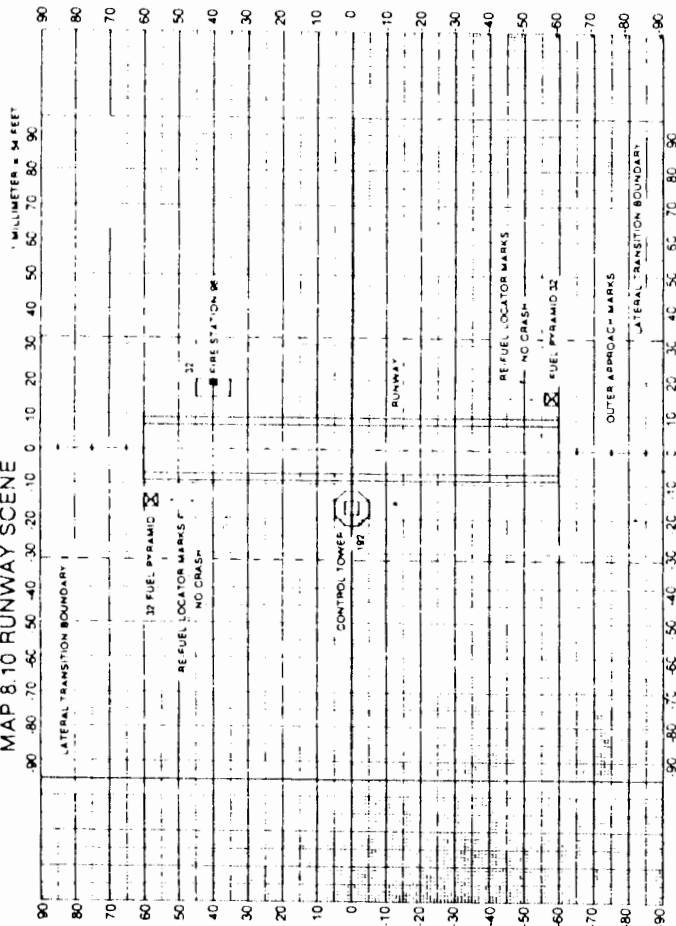


MAP 8.5 WORLD #5 (PRACTICE FIELD)

1 MILLIMETER = 100 FEET



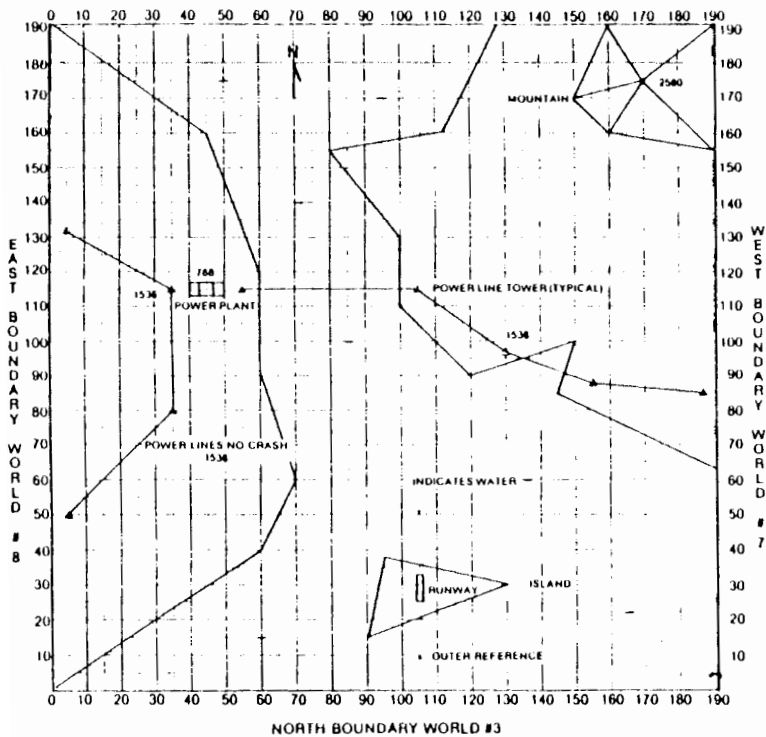
MAP 8.10 RUNWAY SCENE



MAP 8.9 WORLD #9 (POWER LINE RIVER)

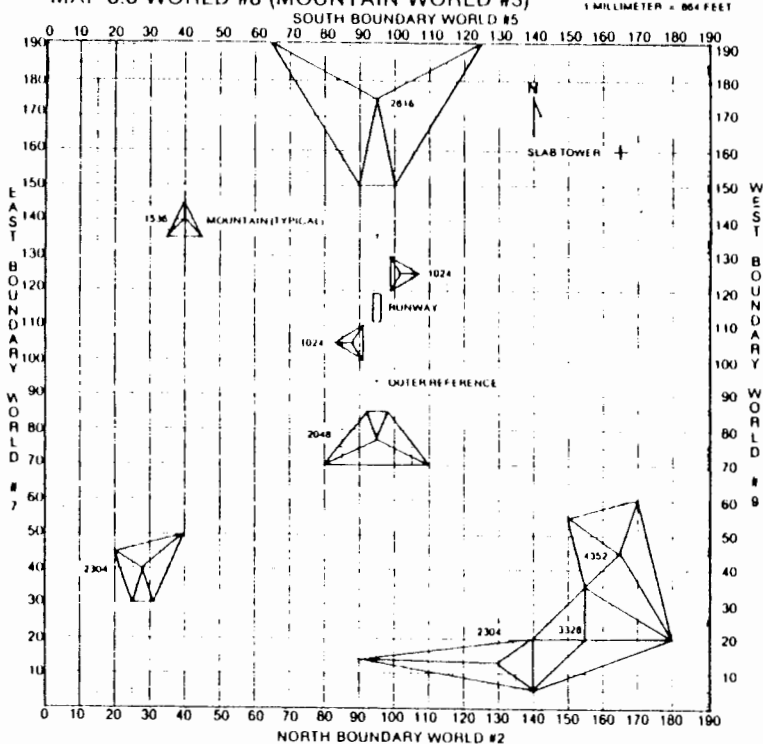
SOUTH BOUNDARY WORLD #6

1 MILLIMETER = 878 FEET



MAP 8.8 WORLD #8 (MOUNTAIN WORLD #3)

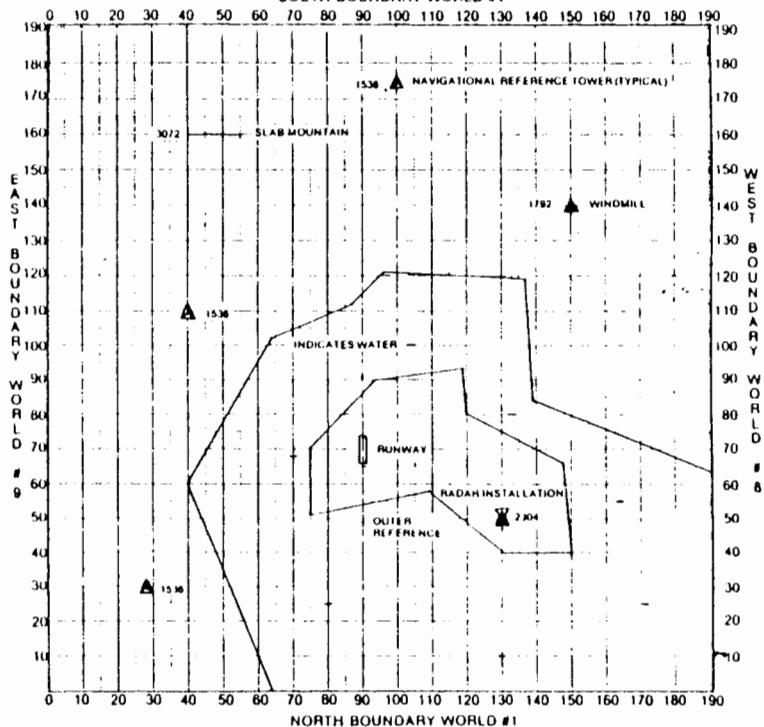
1 MILLIMETER = 064 FEET



MAP 8.7 WORLD #7 (ISLAND BAY)

SOUTH BOUNDARY WORLD #4

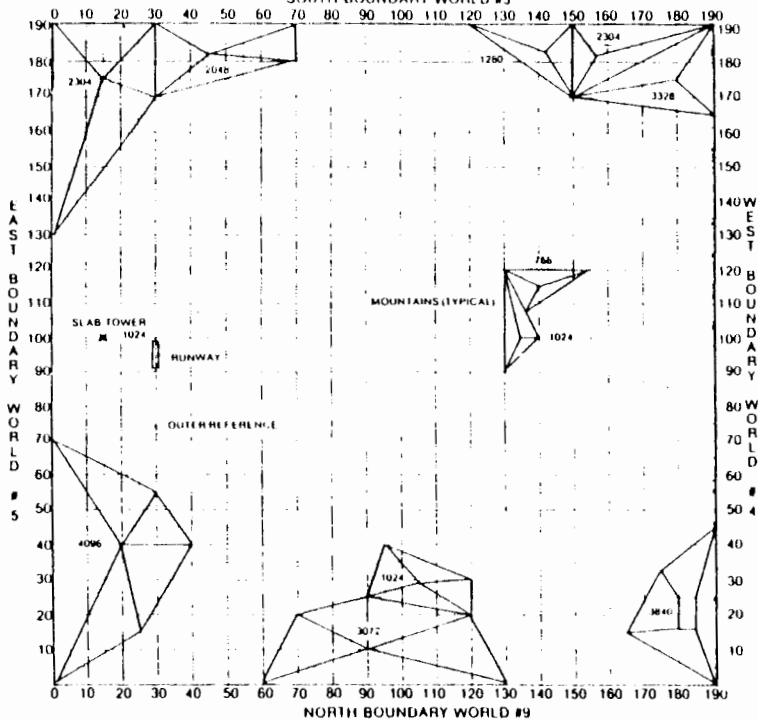
1 MILLIMETER = 864 FEET



MAP B 6 WORLD #6 (MOUNTAIN WORLD #2)

SOUTH BOUNDARY WORLD #3

1 MILLIMETER = 864 FEET



APPENDIX

1. REPRESENTATION OF GRAPHIC VIEWS

The graphic representation of scenery is obviously an important part of any flight simulation which professes to be "view oriented". True 3 Dimensionalism requires that these scenes "grow" or expand as they are approached and that they appear in the proper perspectives from ALL aspects. The mathematics involved with this capability, coupled with the flight dynamics equations of motion, combine to produce a complex set of computational requirements which exceed the minimal mathematics associated with video games. These computational constraints impact the simulation's speed. The desire to have WOF operate from 32K CASSETTE systems as well as disk, eliminated the option of directly accessing disk files, thus freeing up more computer memory and allowing a more elaborate or "faster" program. One desirable feature that this eliminated was the possibility of "solid" or color-filled scenery. However, WOF will never stop itself in the middle of the simulation, read something off the disk, and then proceed as if nothing happened leaving the pilot wondering "what was that?!" The age old trade between memory and speed or capability became the critical issue and a balanced approach had to be struck.

The technique selected was one which creates the scenic views by way of "wire" (or line) graphics. Each world is defined as a series of points. These points are transformed into the aircraft's frame of reference and projected into the 2 Dimensional plane of the craft's windows. The resulting points are then connected by lines and the lines limited or "clipped" to lie on the 2 Hi Res graphic pages which make up the upper half of the TV screen. The main advantage of these methods is that they are MEMORY EFFICIENT and allow the potential for multiple worlds.

2. CONVERSION FACTORS

- 1 NAUTICAL MILE (NM) = 6076 FEET
- 1 STATUE MILE (MI) = 5280 FEET

GIVEN	MULTIPLY BY	TO OBTAIN
NAUTICAL MILES (NMI)	1.151	STATUE MILES (MI)
STATUE MILES (MI)	.869	NAUTICAL MILES (NMI)
KNOTS (NMI/HOUR)	1.688	FEET PER SECOND (FT/SEC)
FEET PER SECOND	.592	KNOTS
KNOTS	1.151	MI/HOUR—M P H.
M P H.	.869	KNOTS

3. SUMMARY OF CONTROL COMMANDS

*****DEFINE WORLDS CONTROL*****

<S>	.....	SET WIND SPEED
<F>	.....	SET DIRECTION OF WIND
<C>	.....	SET CLOUD CEILING
	SET BEGINNING WORLD
<X>	.....	CLEAR WEATHER IN WORLDS
<W>	.....	WORLD SELECT
<ENTER>	.....	EXIT TO SIMULATION

*****FLIGHT CONTROLS*****

FWD/BKWD LEFT STICK	.....	THROTTLE
RT/LT LEFT STICK	.....	RUDDER
FWD/BKWD RIGHT STICK	.....	ELEVATOR
RT/LT RIGHT STICK	.....	AILERON
LEFT BUTTON	.....	TRIM DOWN
RIGHT BUTTON	.....	TRIM UP
BOTH BUTTONS	.....	START ENGINE

<SPACE BAR>	.....	LOWER FLAPS
<->	.....	RAISE FLAPS
<SHIFT><UP ARROW>	.....	RAISE GEAR
<SHIFT><DOWN ARROW>	.....	LOWER GEAR
<BREAK>	.....	WHEEL BRAKES

*****VIEW CONTROLS*****

<UP ARROW>	.....	ELEVATE VIEW 8 DEG.
<DOWN ARROW>	.....	DEPRESS VIEW 8 DEG.
<RIGHT ARROW>	.....	ROTATE VIEW TO RIGHT 90 DEG.
<LEFT ARROW>	.....	ROTATE VIEW TO LEFT 90 DEG.
<CLEAR>	.....	CLEAR WINDOW VIEW TO STRAIGHT AHEAD
<SHIFT><CLEAR>	.....	TOGGLES RADAR VIEW
<Z>	.....	ENLARGES (ZOOMS) RADAR VIEW
<X>	.....	REDUCES RADAR VIEW
<+>	.....	INVERTS THE VIDEO OF ALL GRAPHIC VIEWS

*****SPECIAL CONTROLS*****

<V>	.....	GROUND SPEED
<W>	.....	WEATHER INFO
<S>	.....	ENGINE SHUTDOWN
<F>	.....	RE FUEL

*****PROGRAM CONTROLS*****

<ENTER>	.....	PAUSES SIMULATION
<R>	.....	RESETS SIMULATION